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Ou, Yiyu; Fadil, Ahmed; Ou, Haiyan

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Fabrication of InGaN/GaN nanopillar light-emitting diode arrays

Yiyu Ou^{1,2,*}, Ahmed Fadil¹, and Haiyan Ou¹

¹DTU Fotonik, Technical University of Denmark, DK-2800, Kgs. Lyngby, Denmark

²Light Extraction Aps, Ørsted's plads 343, DK-2800, Kgs. Lyngby, Denmark

*E-mail: yiyu@fotonik.dtu.dk

Abstract— Nanopillar InGaN/GaN green light-emitting diode arrays were fabricated by using self-assembled nanopatterning and dry etching process. Both internal and external quantum efficiency were increased due to strain relaxation and enhanced light extraction.

Keywords— light-emitting diode; nanopillar LED; QCSE

I. INTRODUCTION

In recent years, nitride-based semiconductors have been widely explored for their applications in light-emitting diodes (LEDs) and enormous progress has been achieved including the commercialization of blue LEDs [1]. In order to replace the conventional light sources, LEDs with further improved efficiency are expected. One fundamental limit in LEDs is the low internal quantum efficiency (IQE) caused by the large spontaneous polarization and piezoelectric field due to the large internal strain in multiple quantum wells, known as the quantum confined Stark effect (QCSE) [2]. The other limit is the low light extraction efficiency (LEE) caused by the total internal reflection at different material interfaces.

In this work, nanopillar array has been fabricated on InGaN/GaN green LEDs. Both IQE and LEE were enhanced significantly.

II. FABRICATION AND CHARACTERIZATION

To fabricate the nanopillar structure, a thin SiO₂ interlayer was first deposited on a planar InGaN/GaN green LED epiwafer, followed by the deposition of a thin Au film. The sample was subjected to rapid thermal processing to form self-assembled Au nanoparticles. The nanopattern was transferred from Au nanoparticles to SiO₂ film by reactive-ion etching and further to LED by inductively coupled plasma etching. Nanopillar LED structure with a height of 580 nm was formed and treated by HCl solution to cure the etching damages on the structure surface.

The nanopillar LED and a planar reference LED were then characterized by photoluminescence (PL) measurement and the results were demonstrated in Figure 1. It is seen that the luminescence of nanopillar LED was enhanced by a factor of 4.08. Such considerable enhancement consists of both increased IQE and LEE. The IQE enhancement was caused by a strain relaxation and reduced QCSE. It is confirmed by the blue-shift of the PL emission peak.

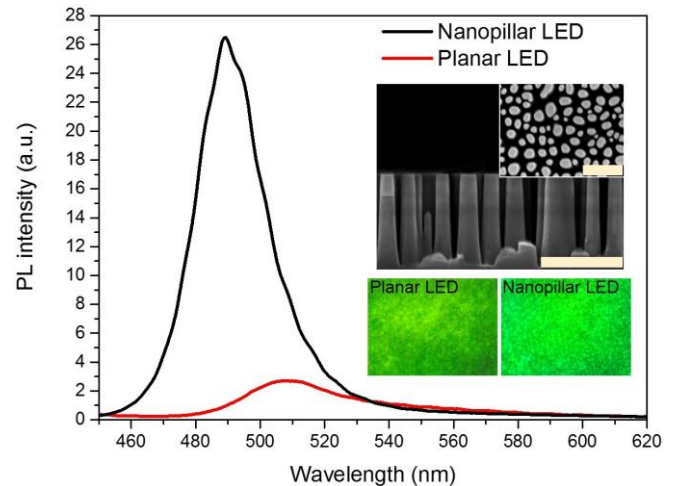


Fig. 1. PL intensity spectra of planar and nanopillar LEDs (inset: upper is cross-sectional and top-view SEM images of the nanopillar structure, both scale bars represent 500 nm; below is microscope photoluminescence images of the two LED samples).

The LEE was also enhanced due to the increased scattering and reduced reflection at the sidewall of the nanopillar structure.

III. SUMMARY

A luminescence enhancement with a factor of 4.08 was achieved by fabricating nanopillar structure on green LED. The promising results suggest that nanopillar LED fabricated by this method is an effective way to enhance the emission efficiency of green LEDs.

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